Experimental and Numerical study of Wake to Wake Interaction in Wind Farms

Machefaux, Ewan; Troldborg, Niels; Larsen, Gunner Chr.; Mann, Jakob; Aagaard Madsen , Helge

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Experimental and Numerical study of Wake to Wake Interaction in Wind Farms

Presenter: Ewan Machefaux

PhD Student, DTU Wind Energy

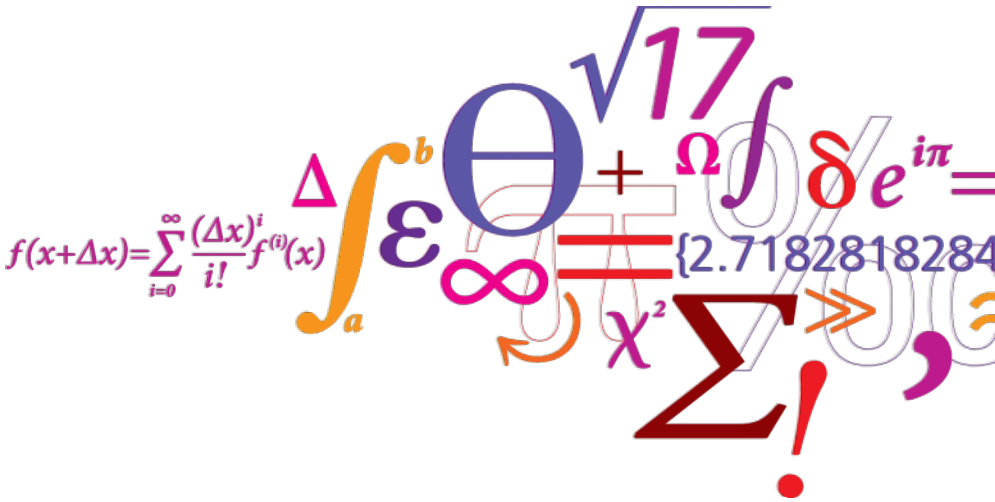
Co-authors (DTU Wind Energy):

Niels Troldborg, Scientist

Gunner Larsen, Senior Scientist

Jakob Mann, Professor

Helge Madsen, Senior Scientist



DTU Wind Energy

Department of Wind Energy

1 – Introduction

Goal:

• continuation of previous CFD study: *Numerical Simulations of Wake Interaction between Two Wind Turbines at Various Inflow Conditions, N. Troldborg et al. 2010*

• aim to contribute to the overall understanding of two interacting wakes

• improve/extend existing the **Dynamic Wake Meandering** model from single wake to multiple wakes

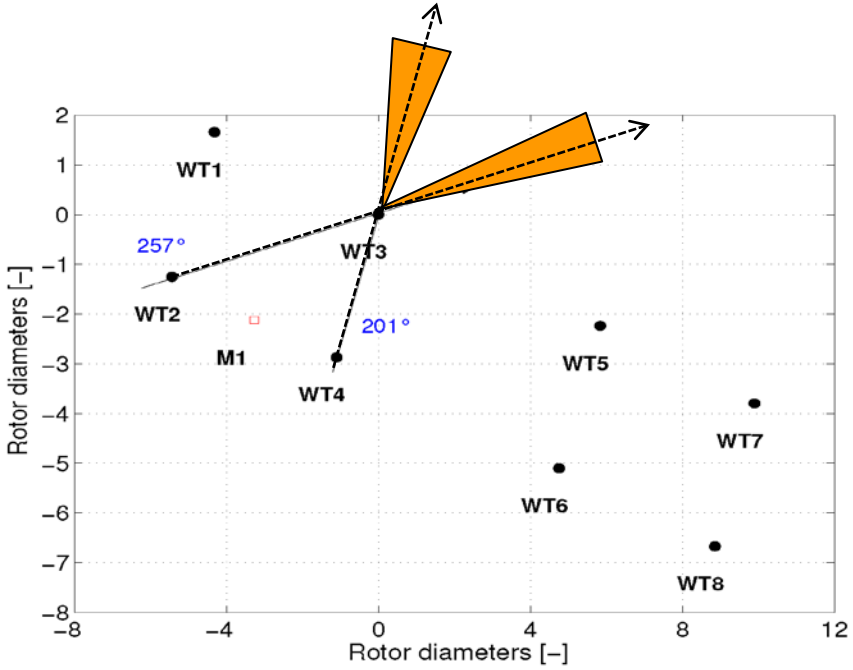
Methodology:

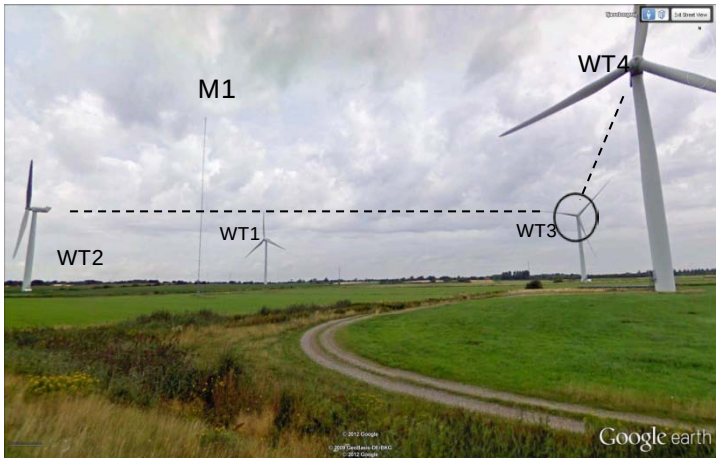
• one-to-one mapping of experimental results on numerical predictions of interacting wakes.

2 - Experimental approach: Tjæreborg site

Tjæreborg **EU-TOPFARM** full scale LIDAR based measurements campaign

- Five NM80-2MW and three V80-2MW (Dong Energy A/S - Vattenfall AB)
- **WT3** LiDAR mounted
- **QinetiQ** ZephIR Continuous Wave Lidar
- **M1**: 93m mest mast
- 2 selected double wake directions
- **2 timeseries** analyzed

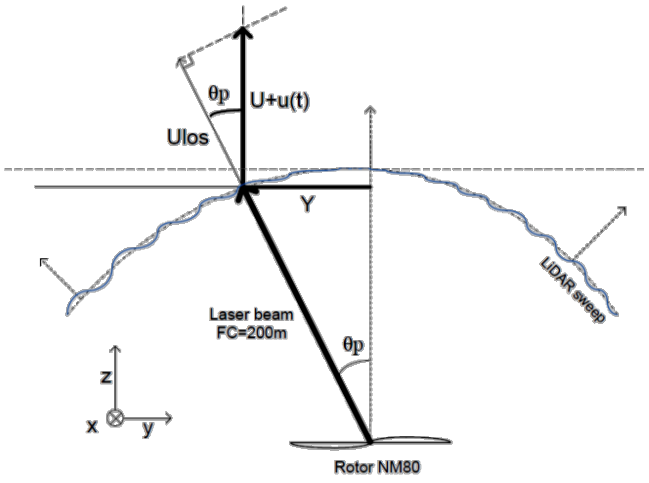




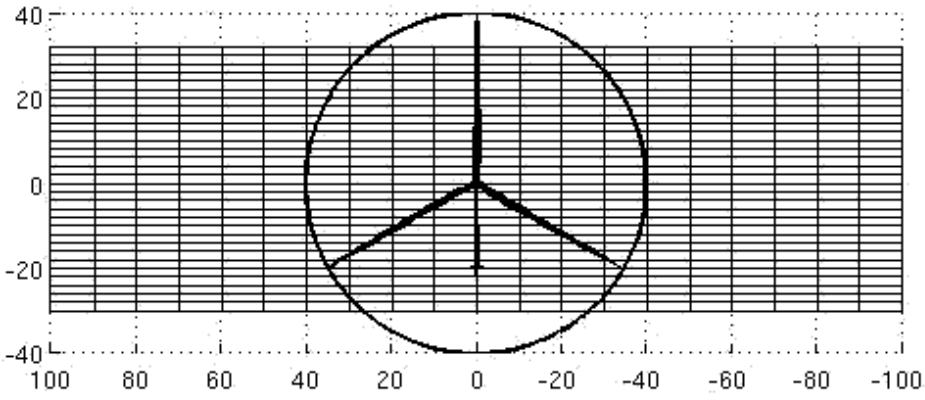
2 - Experimental approach: wake resolving

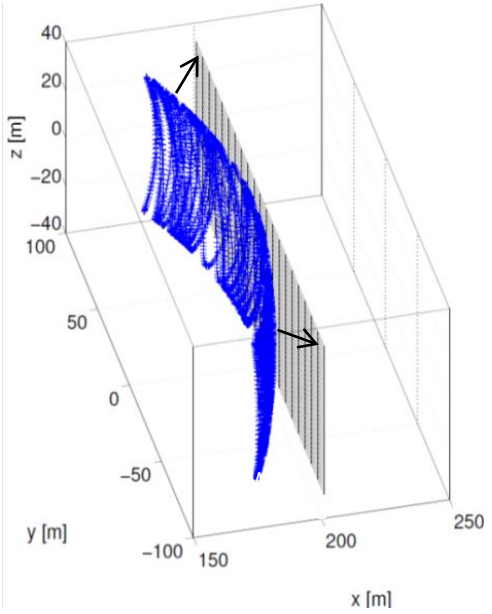
General methodology for wake resolving

1. **Computation** from Doppler Spectra to line-of-sight velocity *Ulos*
2. **Filtering** of bad measurements
3. **Discretization**: 2 x 10 m² (cell center in red)
4. **Projection** due to tilting and panning of the laser beam



Scanning pattern of CW LiDAR

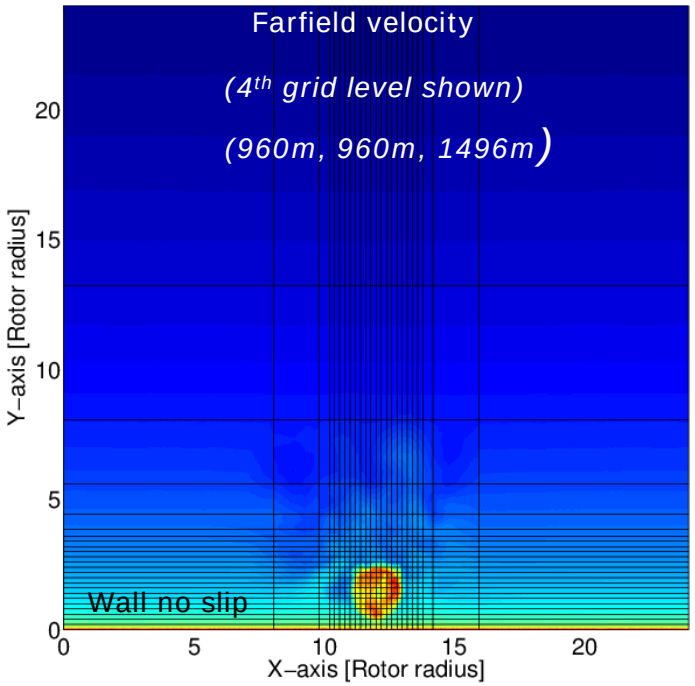


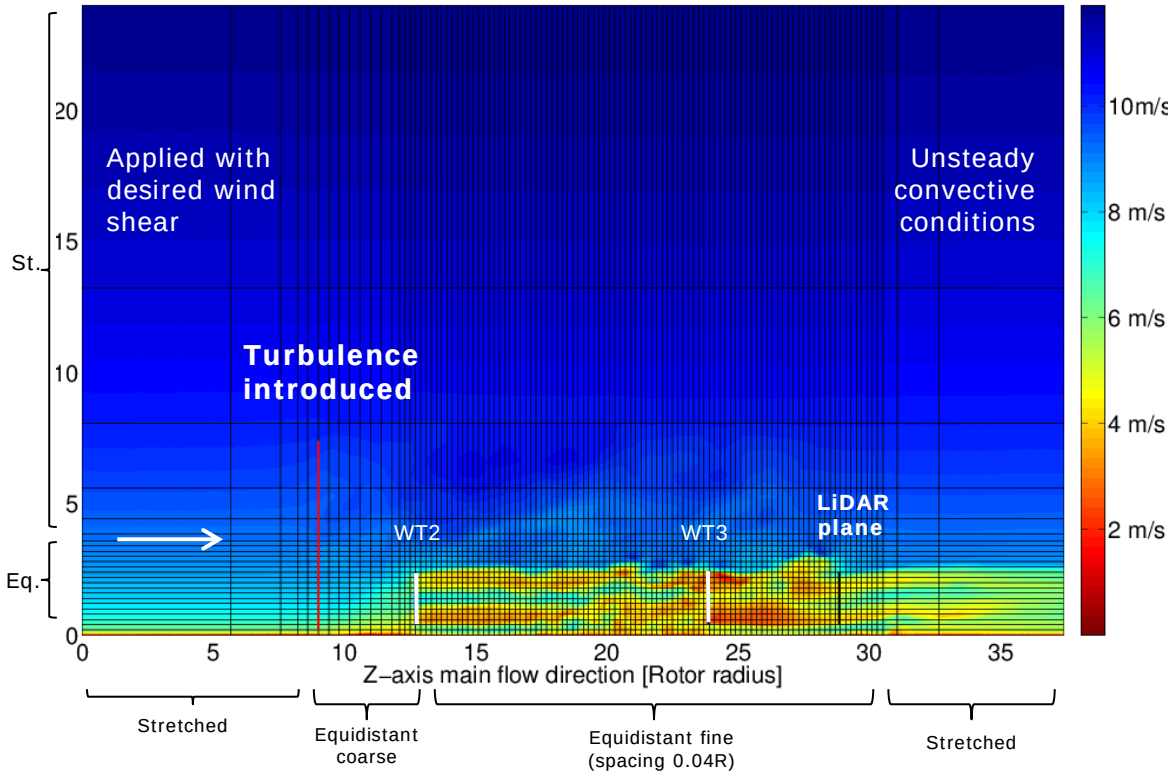


3 – Numerical approach: computational set up

Key features:

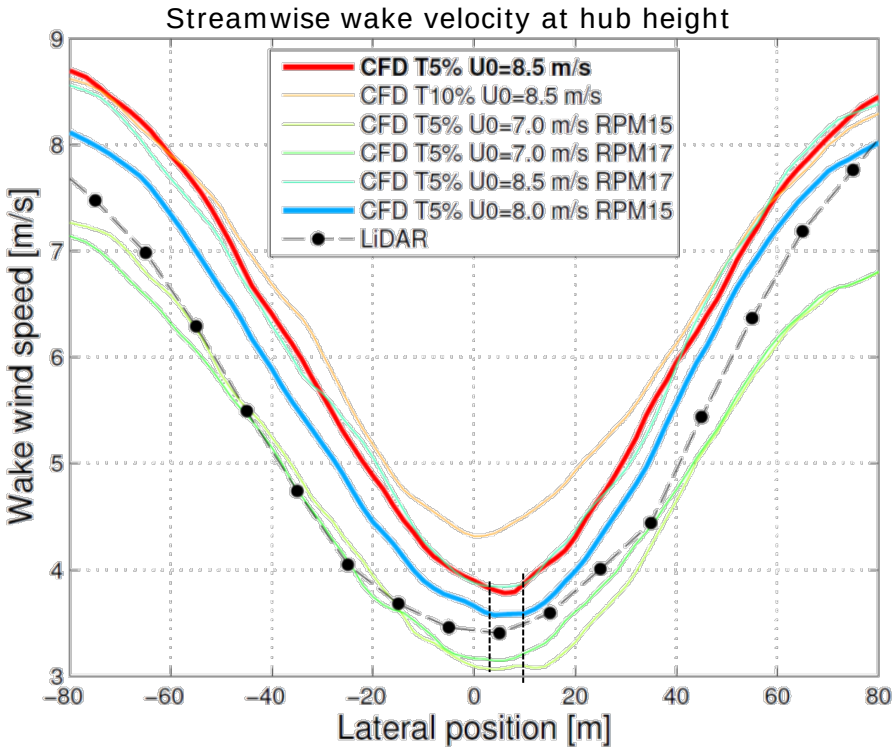
- **EllipSys3D** flow solver ; **Actuator Line Technique ; Large Eddy Simulation**
- **ABL** modeled:
  - **shear**: steady body forces computed and applied in the entire domain
  - **synthetic turbulent** fluctuations, **Mann model**
- Constant RPM, constant pitch, no yaw
- **2 grids** (large spacing:3.98M & low spacing:2.95M cells)
- Unsteady computations: 10 minutes flow field statistic

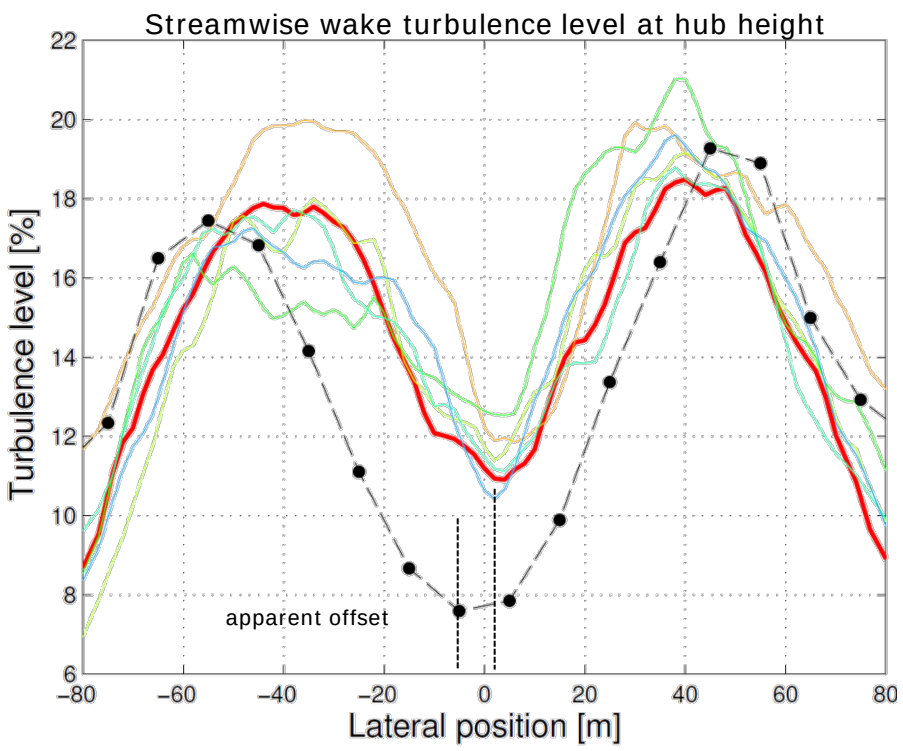




4 – Results: case 1 with large spacing

2.5D downstream; ≈5.5D turbine spacing; U_0=8.5 m/s



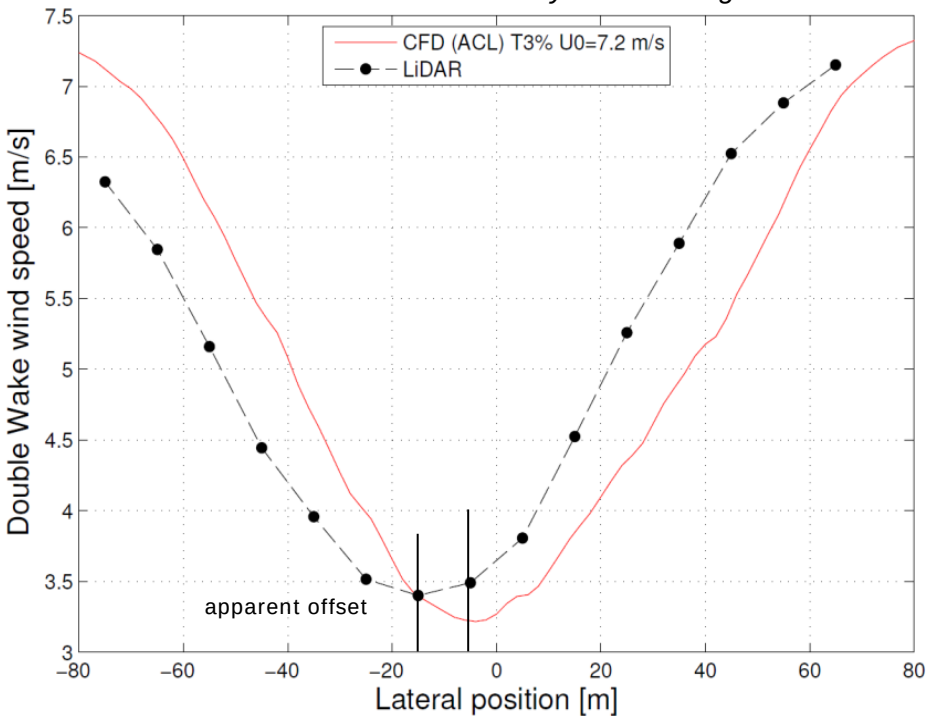


TI [%]; U0 [m/s]; RPM [-]	Rel. error WT4 [%]	Rel. error WT3 [%]	Rel. error power ratio [%]
5%; 8.5m/s; 15 (measured)	13.20	18.34	5.92
10%; 8.5m/s; 15	5.52	35.16	31.37
5%; 7.0m/s; 15	-56.03	-47.60	5.41
5%; 7.0m/s; 17	-47.04	-34.74	8.37
5%; 8.5m/s; 17	9.14	19.10	10.97
5%; 8.0m/s; 15	-2.84	3.43	6.09

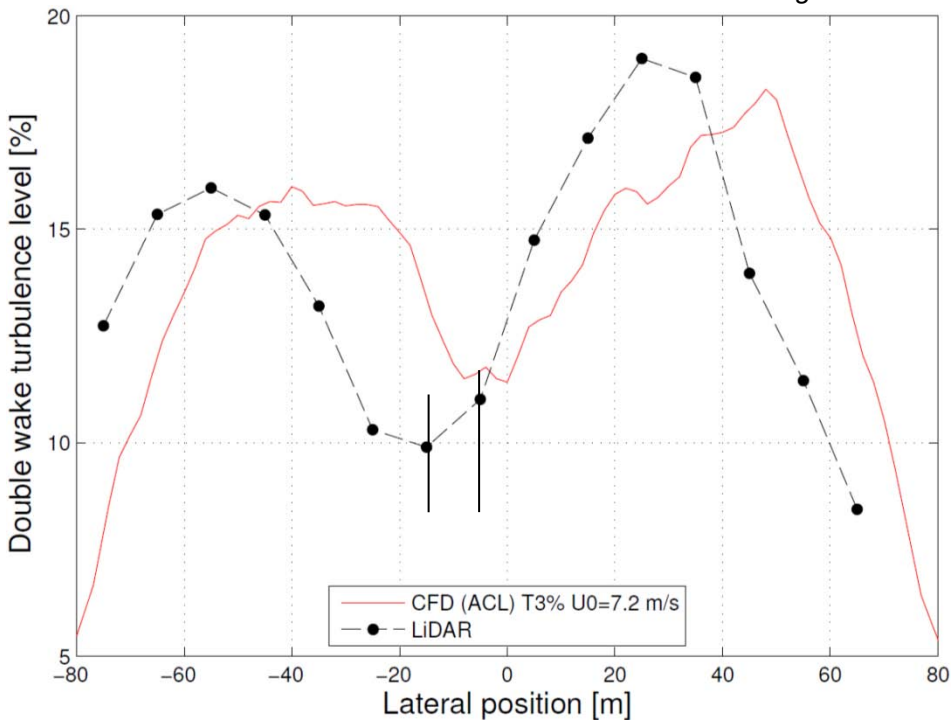
4 – Results: case 2 with low spacing

2.5D downstream; ≈3D turbine spacing; U0=7.24 m/s

Streamwise wake velocity at hub height



Streamwise wake turbulence level at hub height



Quantification of the offset?

Cross correlation study: ≈ 5m at 200m → 1.5deg error

4 – Conclusions

• Good agreement (high correlation) on organized flow structure part of the wake

• Offset consequence of yaw/mounting misalignment

… need to overcome the present limitations

• 10min averaged quantities → limitation in time and spatial resolution in the measured wake

• Only in the fixed frame of reference

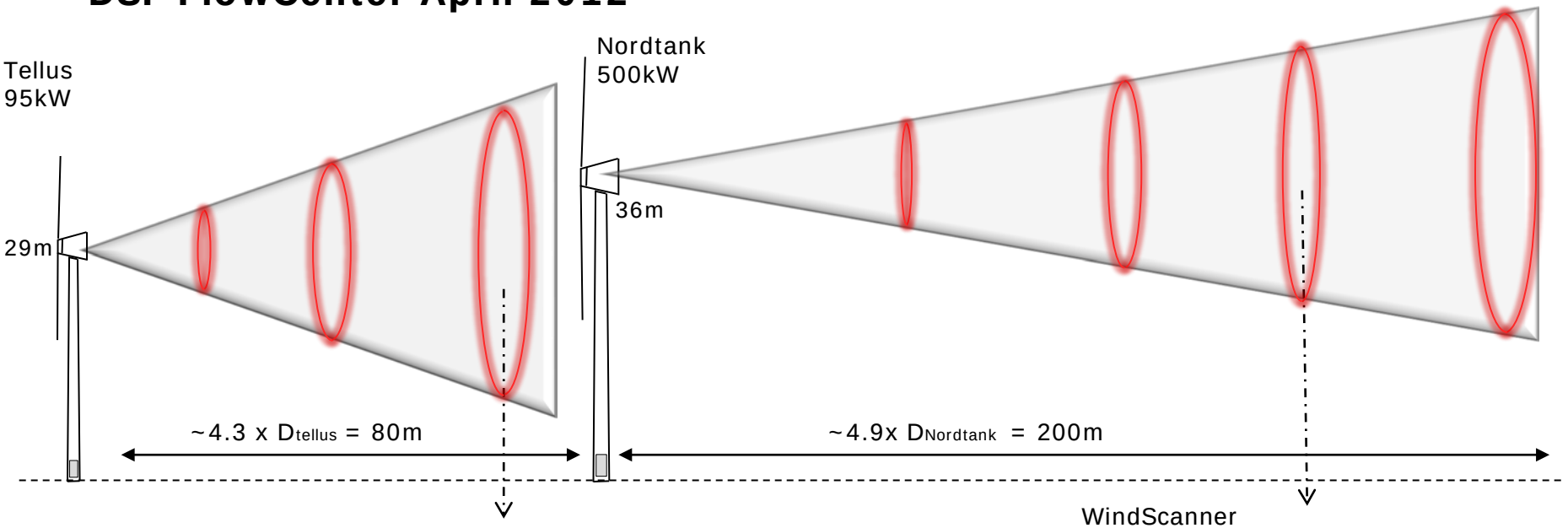
• Only one downstream cross section

• No knowledge of the single wake flow field upstream of the second rotor

→ New merged wake experiment (April 2012)

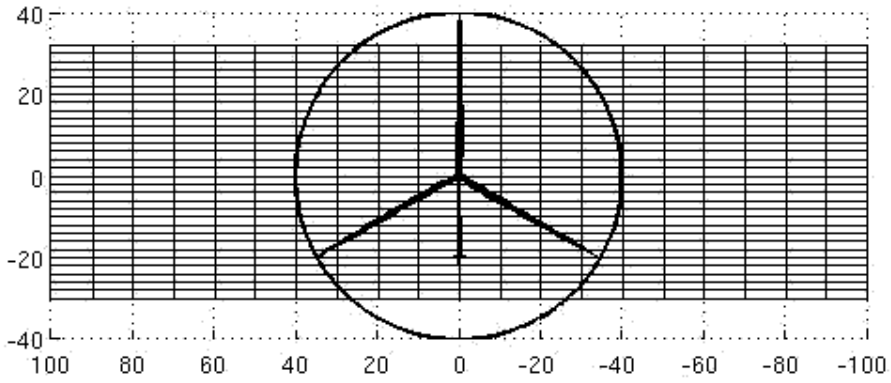
5 - Future merged wakes experiment

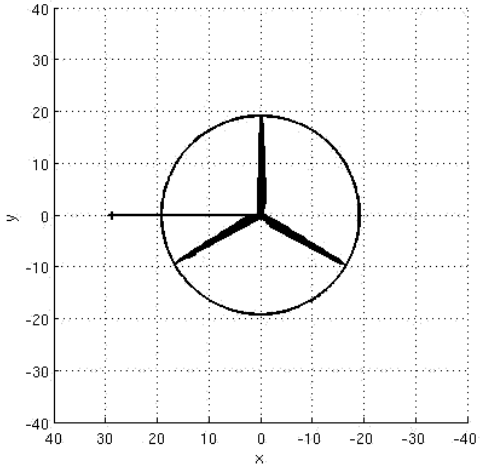
DSF FlowCenter April 2012



WindScanner

CW LiDAR





5 – Future merged wakes experiment

Future experiment strengths:

- high spatial and time resolution
- several planes can be scanned at a time
- turbulence structures, meandering, expansion and recovery of the wake can be investigated
- the use of 2 LiDARS will enhance knowledge of the inflow to the downstream turbine

Acknowledgment: Dong Energy, DSF Flow Center, EU-TOPFARM

Thank you for your attention